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INTERSYSTEM INTERFERENCE STUDY BETWEEN DVB-T AND UMTS

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ABSTRACT
The transition from analogue to digital broadcasting releases some spectrum that could be used for other services than broadcasting. However, the inter-system interference occurring between different radios systems like DVB-T limits the maximum utilization of the released spectrum. Since a detailed mathematical analysis of getting the optimum guard band alongside the physical separation distance between the transmitters of the Radio Access Networks (RANs) is yet to be produced, this work therefore focuses on developing a mathematical model to evaluate inter-system interference between DVB-T and UMTS radio systems based on a geometrical structure approach of the spectral mask bearing in mind DVB-T as the down-link victim. This therefore translates to the Adjacent Channel Interference (ACI) area between the two radios and the resultant ACI could then be calculated in terms of the DVB-T and UMTS spectral parameters. An interference calculator that reflects graphical representation at various signal strengths, interference levels and its corresponding effect on quality of service are hence produced.

KEYWORDS: RAN, ACI, OFDM, Signal Strength, Outage Probability, DSA

INTRODUCTION

Digital Video Broadcasting Terrestrial (DVB-T) can be put in adjacent bands to Universal Mobile Telecommunications System (UMTS) operating in Bands I-V. For the purpose of this study, the core band has been identified i.e. 1900 band. If DVB-T is to be placed near this band, adjacent channel interference would occur which would degrade signal quality for DVB-T reception and even decrease capacity in the UMTS network.

The main form of interference is adjacent channel interference (ACI) which ensues when the systems are operating in adjacent bands to each other. ACI occurs due to non-idealities in transmitter and receiver. Imperfections with transmitter filter gives rise to energy leakage into adjacent spectrum band. Interferences in the same cell as well as other cell interference would also be considered and their effects on capacity and quality of service.

Various studies have been carried out to find out how these systems can co-exist with a significant reduction in intersystem interference to maximize capacity, invariably increasing revenue for the operators whilst making maximum use of the spectrum. The use of a technique called Dynamic Spectrum Allocation would be seen as an elixir to the impeding co-existence problem. An interference calculator would be derived which could corroborate the already existing tools e.g. Minimum coupling loss, Monte Carlo, Semo simulation tool and SEAMCAT tool.

This paper therefore focuses on developing a mathematical model to evaluate inter-system interference between DVB-T and UMTS radio systems based on a geometrical structure of the spectral mask and finding its corresponding effect on quality of service bearing in mind DVB-T as the down-link victim.

THE DYNAMIC SPECTRUM ALLOCATION

In DSA, the width of the spectrum block assigned to a Radio Access Network (RAN) is allowed to vary in order to allow for changing demands, by adding more carriers at the end of the allocated block of spectrum. Interference can be controlled between the RANs as only one guard band is required between each RAN, which is ensured that it is always kept adequate in size. This technique needs a minimum of co-ordination between the RANs as the only aspect that controls the spectrum portioning in the location of the main guard band or the frequency channel separation.

In lieu of this impending problem enumerated, this paper aims to study in a typical case “intersystem interference between DVB-T and UMTS: DVB-T as a Down-link victim”.
It would be seen that when DSA occurs, there would be spectrum overlap in the DSA boarder regions giving rise to adjacent channel interference between the two radio systems in question (Hamacher, Ch.2002)

In order to maintain considerable quality of service and (or) grade of service, interference management objective are as follows:

1. Minimizing interference
(a) Reduce spectral overlap
(b) Decreasing the number of user terminals
2. Maximizing available wanted power
(a) Decreasing average user terminal distance
(b) Increasing total available Base station power
(c) Decreasing the number of user terminal.

In UMTS with a frequency re-use of 1, increasing the number users creates an increase in interference level thereby decreasing capacity. Therefore solution is given as in 1(b). Reducing the size of the UMTS cell makes power to be available down link to the UMTS mobiles for optimum QOS hence solutions 2(a) and 2(c) becomes viable.

DVB-T is a single frequency network, essentially a broadcast system, with no power control unlike other mobile systems. In this case limiting the number of terminals does not degrade signal quality. Therefore 1(a), 2(a) and 2(b) are goals that should be achieved (Leaves, etal, 2004).

DVB-T and UMTS interference scenario
It would be noticed from Figure.1, the interference scenarios as it affects the DVB-T receiver, which we consider to be in receive only mode that the interfered receiver is posed with interferences from the UMTS mobiles transmitting in an "Uplink fashion" in their contained cells and UMTS base station in "down-link" fashion in cell A and neighbouring UMTS cells. Usually, interfering mobiles in a distance above 100meters should not contribute to perceived interference level at the DVB-T receiver. When the DVB-T receiver is close to the UMTS base station while being further away from its own transmitter, Blind spots may ensue, blocking totally or degrading severely the wanted signal as seen in Figure.1. Cell A is dotted so as to indicate high region of interference.

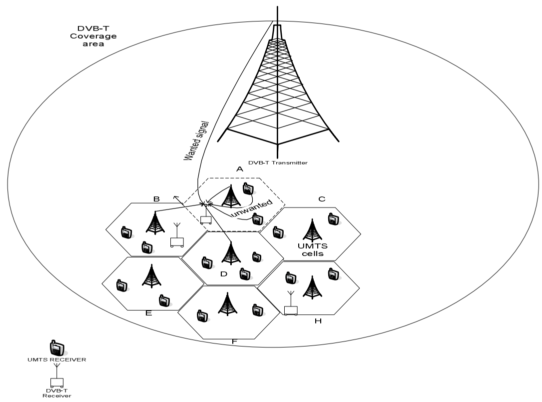


Figure.1 showing the interference scenario

Since the radio access networks are UMTS with a frequency reuse of 1 and a DVB-T operating at a single frequency network, all the base stations and the transmitters in each of networks are able to use the same frequencies. DVB-T is currently specified for bandwidths of 6,7 and 8 MHz . These may be reduced to 5MHz with which the UMTS operates by a reduction of the orthogonal frequency division multiplexing (OFDM) sub-carrier spacing to give 5MHz with no reduction in data rate but at the expense of large signal degradation. Since DVB-T is a broadcast system, the same content is transmitted from all cells hence handovers typically does not fail. Call drops is largely due to inadequate received signal strength.

Since the main interference considering DVB-T as a down link victim is Adjacent Channel Interference, it is therefore of importance that an equation be derived to take account of this.

Studies using Adjacent Channel protection ratio (ACP), adjacent channel leakage ratio (ACLR), Adjacent channel selectivity and sensitivity (ACS) are based on manufacturers design embedded in the Digital signal processors (DSPs) of the mobile. This has been standardized by 3GPP by defining filter masks and identifying minimum values for filters at 5 and 10MHz. (3gpp.org, 2010)

DVB-T has a wider bandwidth than UMTS, transmitting at Very high power of about 20KW and UMTS power of about 43dBm. Hence $P_{T\,DVB\text{-}T} >> P_{T\,UMTS.}$ (Owens, *et al*, 2006)

METHODOLOGY

Adjacent Channel Interference (A Geometric Approach)

The major aim of this study is to calculate the area of the spectral overlap between two Radio Access Network operating in adjacent bands to each other. This translates to Adjacent Channel Interference (ACI) area. The resultant ACI would be calculated in terms of the DVB-T and UMTS spectral parameters.

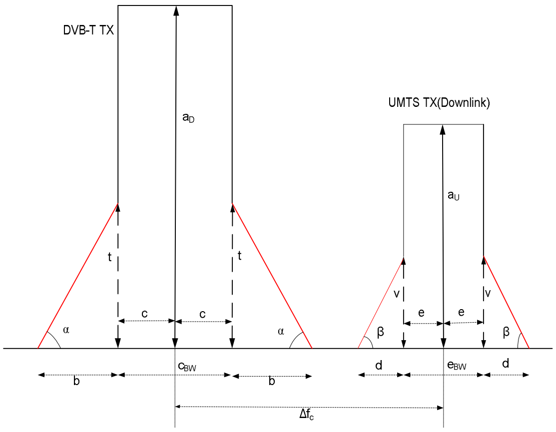


Figure.2: Spectra mask of DVB-T Transmitter with UMTS Transmitter (downlink)

Figure.2 depicts the spectra co-existence of DVB-T TX and UMTS TX (downlink), this is because the main contributing source of interference to a DVB-T system is UMTS downlink.

a_D is the height of the DVB-T TX spectral mask and is proportional to the transmitted power.

a_U is the height of the UMTS TX(down link) spectral mask, also proportional to the transmitted power.

α and β respectively are angles made by the interfering regions of DVB-T TX and UMTS TX (downlink).

C_{BW} and e_{BW} are the bandwidths of the DVB-T and UMTS spectrum respectively.

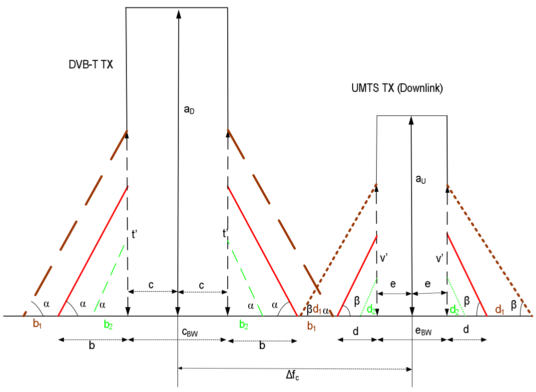


Figure.3 Variation of interference region

This figure(3) shows a typical case of how we intend to vary the interference regions from say b in the DVB-T TX mask to b1 or b2 and also vary d to say d1 and d2 and their effect on signal to interference ratio and hence capacity. A reduction or an increase in theses interference boundaries would cause a corresponding increase or decrease in t denoted as t′ as seen above.

It should be noted that their respective angles remain the same along the reference x- axis.
Going back to figure (2) and bringing the masks close to each other, in such a way that the interference regions of participating spectrums intersect. There would then be a resultant interference called the Adjacent Channel Interference (ACI) depicted by the ACI region in Figure.4

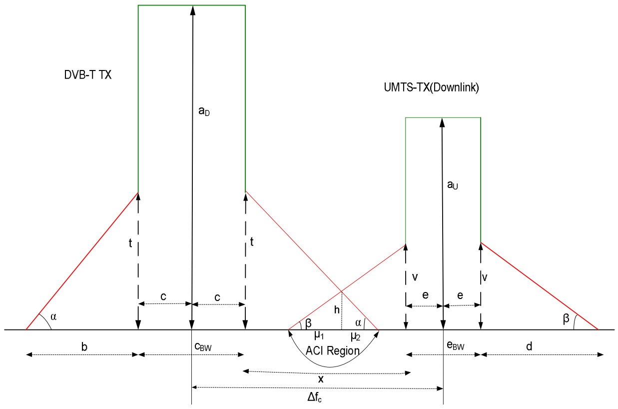


Figure.4 Spectral masks close to each other

When the spectral masks are close to each other because of their operation in adjacent bands, Adjacent Channel interference would result, as depicted in The ACI region of Figure.4.

Using pure geometry, we would like to get the area of this ACI region which directly translates to the Adjacent Channel Interference. This Area would be derived in terms of b, d, c, e, Δf_c and the participating angles

Consider Figure.5, which is an expanded view of ACI region bounded by x.

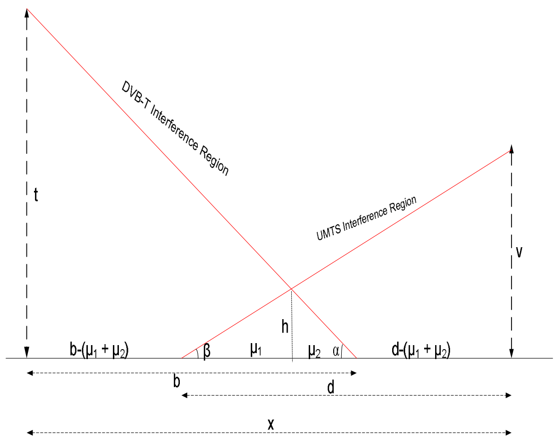


Figure.5 Scaled view of the interference region

The following can be deduced from Figure.5

$$\tan\beta = \frac{h}{\mu_1}, \qquad \tan\alpha = \frac{h}{\mu_2}$$

$$\mu_1 = \frac{h}{\tan\beta}, \qquad \mu_2 = \frac{h}{\tan\alpha}$$

$$\mu_1 + \mu_2 = h\left(\frac{1}{\tan\beta} + \frac{1}{\tan\alpha}\right) \qquad (1.1)$$

The aim here is to calculate the area of the triangle which actually translates to the Adjacent channel Interference (ACI) bounded by the ACI region.

We deduce from Figure.5 that:

$$X = b - (\mu_1 + \mu_2) + (\mu_1 + \mu_2) + d - (\mu_1 + \mu_2)$$

$$X = b + d - (\mu_1 + \mu_2)$$

$$\mu_1 + \mu_2 = b + d - X \qquad (1.2)$$

Equating (1.1) to (1.2)

$$h\left(\frac{1}{\tan\beta} + \frac{1}{\tan\alpha}\right) = b + d - X$$

$$h = \frac{b + d - X}{\left(\frac{1}{\tan\beta} + \frac{1}{\tan\alpha}\right)} \qquad (1.3)$$

Calculating the Area of the ACI region

$$Area\ (ACI) = \frac{1}{2}(\mu_1 + \mu_2)h \qquad (1.4)$$

$$= \frac{1}{2}(b + d - X)\frac{(b + d - X)}{\left(\frac{1}{\tan\beta} + \frac{1}{\tan\alpha}\right)}$$

$$Area\ (ACI) = \frac{1}{2}\frac{(b + d - X)^2}{\left(\frac{1}{\tan\beta} + \frac{1}{\tan\alpha}\right)} \qquad (1.5)$$

Considering Figure 3.2

$$\Delta f_c = c + X + e$$

$$X = \Delta f_c - c - e \qquad (1.6)$$

Substitute (1.6) in (1.3)

$$h = \frac{b + d + c + e - \Delta f_c}{\left(\frac{1}{\tan\beta} + \frac{1}{\tan\alpha}\right)} \qquad (1.7)$$

Insert (1.6) in (1.5)

$$Area\ (ACI) = \frac{1}{2}\frac{(b + d + c + e - \Delta f_c)^2}{\left(\frac{1}{\tan\beta} + \frac{1}{\tan\alpha}\right)} \qquad (1.8)$$

This is an important equation as it reflects the Adjacent Channel interference (ACI) analytically using a geometrical approach where b and d can be varied.

Typical Scenario (UMTS as the only Interferer)
A typical scenario considered here is assuming that the major source of interference is from the UMTS.
The assumption made is that the DVB-T spectral mask is perfectly rectangle i.e negligible or no interference. And the only source of interference is from the UMTS system. Figure.6 depicts this.

$$Area\ (ACI) = \frac{1}{2}\frac{(b + d + c + e - \Delta f_c)^2}{\left(\frac{1}{\tan\beta} + \frac{1}{\tan\alpha}\right)} \qquad \text{From (1.8)}$$

Considering figure.4 and following the aforementioned assumption means that:
b tends to zero or ideally zero
α tends to 90º , therefore Tan α becomes very large and tends to infinity.

UMTS operates close to the DVB-T TX in the adjacent bands.
Hence (1.8) becomes:

$$Area\,(ACI) = \frac{1}{2}\frac{(d+c+e-\Delta f_c)^2}{\left(\frac{1}{\tan\beta}\right)} \qquad (1.9)$$

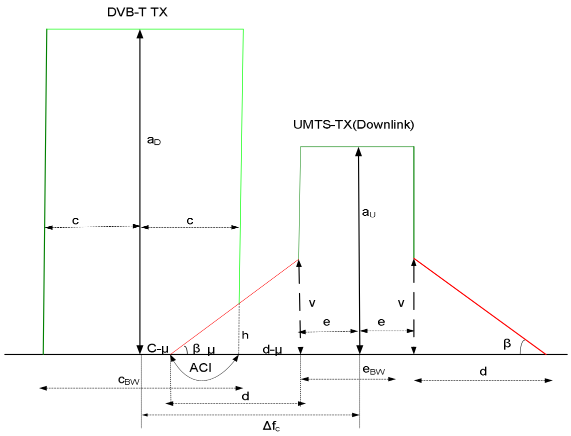


Figure.6 UMTS is the only interferer, DVB-T assumed to be perfectly rectangle.

DVB-T wanted signal
Consider a scenario where the DVB-T receiver receives a signal power S_{DVB-T} from the DVB-T transmitter. However the actual power received is affected by Free space loss different path loss models can be identified. But for the sake of simplicity, we use the path loss equation given as:

$$FSL\,(dB) = 32.45 - 20\log X\,(Km) + 20\log f_{dvb-T}\,(MHz) \quad (3.12)$$

Hence the wanted signal power as perceived at the DVB-T receiver (dBm) = The signal power from the DVB-T transmitter (dBm) – Free space loss (FSL in dB)

$$S_r = S_{DVB-T} - FSL$$

Hence, signal to Interference ratio at the DVB-T receiver is given as

$$\frac{S_r}{I_{Total} + ACI + N_{Thermal}}$$

Which must be less than a certain threshold for conducive reception and decoding at the DVB-T receiver.

It sufficient to say $I_{sc} + \sum_{i=1}^{6} I_{(oc)_i} = I_{Total}$

I_{Total} =0, this is because ACI dominates the interference, degrading the wanted signal badly due to operation in adjacent bands. The signal to Interference ratio is hence given as:

$$S/I = \frac{S_r}{ACI + N_{Thermal}}$$

Thermal noise is always an intrinsic part of any communications system.

Taking into account all parameters involved gives the equation below:

$$S/I = \frac{S_r}{\sum_i^7 (S_{ACI}\ M_i \bar{V}) - PL_i + N_{Thermal}}$$

$$S/I = \frac{S_{DVB-T} - FSL}{\sum_i^7 (S_{ACI}\ M_i \bar{V}) - PL_i + N_{Thermal}} \quad 1.10$$

This is a very important formula which would be used in our analysis.
M, and $\bar{V}$ are constants (voice activity factor and number of UMTS user in the cell respectively)

Transforming Area (ACI) to its equivalent Leakage Power
The Area under the graph of the UMTS spectral mask is proportional to the Transmit Power S_{UMTS} and say the Area of the ACI region is proportional to its interference power (S_{ACI}) .

$$S_{UMTS} \propto A_{UMTS} \text{ and } S_{ACI} \propto Area(ACI)$$

$$S_{UMTS} = G.A_{UMTS} \text{ and } S_{ACI} = G_1.Area(ACI)$$

where G and G_1 are constant of proportionalities respectively.
Take G=1.2 and G_1=1 ,

Consider Figure.6, and assume the spectral mask to be that of the UMTS mobile, the Area of the UMTS spectral mask, now uplink is gotten as:

$$A_{UMTS} = e_{BW}.a_{uu} + d.v$$

Hence

$$S_{ACI} = \left(\frac{Area(ACI)}{A_{UMTS}}\right) S_{UMTS}$$

$$S_{ACI} = \left(\frac{\frac{1}{2}\frac{(d + c + e - \Delta f_c)^2}{\left(\frac{1}{\tan\beta}\right)}}{G(e_{BW}.a_{uu} + d.v)}\right) S_{UMTS} \qquad (1.11)$$

Where S_{ACI} is in mW and can be converted to log scale in dB.
The all encompassing formula for signal to interference ratio is given below:

$$S/I = \frac{S_{DVB-T} - FSL}{\sum_i^7 (S_{ACI}\ M_i \bar{V}) - PL_i + N_{Thermal}} \qquad (1.12)$$

Where S_{DVB-T} = 74dBm and is the transmitted power of the DVB-T Transmitter
FSL is the free space loss for DVB-T
S_{ACI} is earlier defined and is given by equation (1.11)
M_i is assumed number of users in "i" cells and $\bar{V}$ is voice activity factor since not all users speak at the same time; this is taken to be 0.4.
PL_i is the path loss of the mobile

$N_{Thermal}$ = DVB-T thermal Noise(KTB) +DVB-T receiver Noise figure = -98dBm+7

$N_{Thermal}$ = -91dBm.

With all our parameters gotten, Δf_c can now be varied using the programme written and its effect on Signal quality.

Intuitively, the effect of the UMTS mobiles is usually very small owing to their low transmitting power as compared to its base station hence a reason to study the ACI effect considering the UMTS down link.
UMTS down Link (DL) Effect on DVB-T TX

Figure.7 shows a pictorial view of the scenario, considering one tier of the UMTS topology consisting of seven UMTS cells in the coverage of a DVB-T Transmitter.

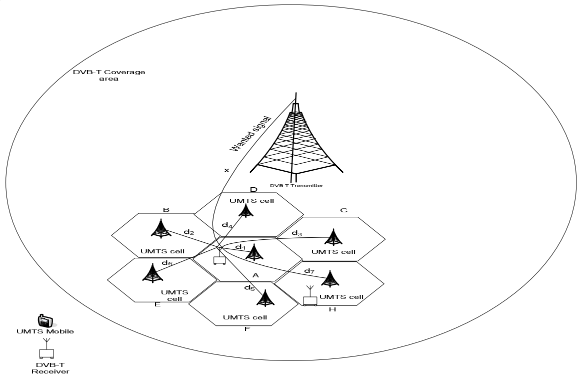


Figure.7 DVB-T receiver interfered by UMTS Base Stations at varying distance d_i

Figure.7 shows how the UMTS Base station interferes with the DVB-T receiver at various distances d_i. In this scenario the DVB-T signal would be badly degraded if the DVB-T transmitter operates at an adjacent band to any of the UMTS cells in which the DVB-T receiver is located. For example if the DVB-T TX operates in an adjacent band to UMTS cell A, ACI would degrade the received DVB-T signal but its effect would be minimal or null in other UMTS cells (B,C,D,E,F, and H) considering that proper frequency planning has been carried out to avoid Co-channel and Adjacent Channel interference in UMTS system.
A more concrete view of the task is shown in Figure.8

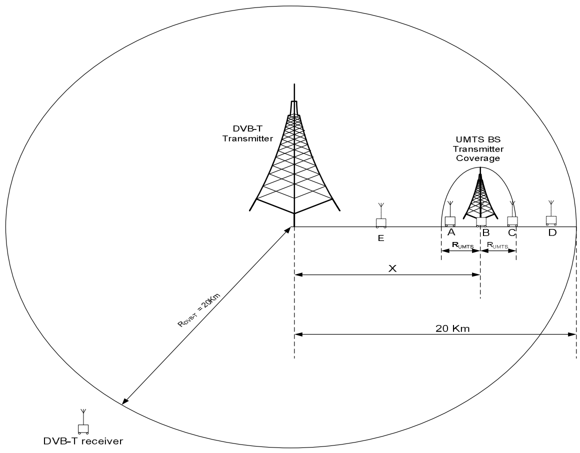


Figure.8 DVB-T receiver under UMTS coverage operating in Adjacent Bands with UMTS BS at distance X from the DVB-T transmitter.

Assuming the radius of the interferer coverage is R_{UMTS} which is assumed to be 1km and X is the distance between Interferer and DVB-T Transmitter. The radius of the DVB-T coverage is taken as 20Km. Observe the location of the receiver at position A which would be varied in steps to position B and then to position C. The aim here is to find the most convenient distance X at which the two base stations in question could be separated and at what Channel frequency separation Δf_c.
At any Position , other than in the interfering coverage say at position E and D where there may not be a UMTS coverage or a coverage, but not operating in Adjacent bands then ACI becomes negligible and DVB-T signal would only reduce with its associated Free space loss.

If however, it operates in adjacent bands in the scenario depicted in Figure.8, the task then would be to find how the received DVB-T and ACI power varies within the UMTS coverage at distances between X- R_{UMTS} and X+ R_{UMTS}.

$$PL_i(dB) = 32.45 + 20\log d_i(Km) + 20\log f_{UB}(MHz) \qquad \text{From} \quad (3.11)$$

Where f_{UB} is the UMTS frequency in the Uplink and PL_i (dB) is the varying path loss defined by X- R_{UMTS} and X+ R_{UMTS}.
In order to achieve this, equation 1.12 becomes:

$$S/I = \frac{S_{DVB-T} - FSL_i}{(S_{ACI} - PL_i) + N_{Thermal}} \quad (1.12)$$

Where $i = X - R_{UMTS} : X + R_{UMTS}$ in Km and for convenience in computation and clarity when plotting the graph, i would be converted to meters as $i = (X - R_{UMTS}) * 1000 : (X + R_{UMTS}) * 1000$ but would be divided by 1000 when solving for the distance in the Path loss equations.

At this point an extensive knowledge has been gained on the Topic "Intersystem Interference study between DVB-T and UMTS: DVB-T as the down link victim"
Hence a Matlab code is therefore written and several graphs of DVB-T and ACI signal strength under the UMTS coverage can be plotted coupled with the Signal to interference ratio.
For a measure of Signal to interference ratio the European Broadcasting Union says for reasonable decoding of the DVB-T signal the Signal to interference ratio should be greater than or equal to 10dB (EBU, 2006).

SIMULATION AND TESTING

Simulation

In the simulation carried out, the guard band was varied for 0, 1, 2, 3.5, 5, 6, and 8.5 MHz respectively. The distance X (Km) between the DVB-T transmitter and the UMTS Base station (interferer) was also varied at 0, 0.5, 1, 2.5, 5, 7.5,10, 12.5, 15 and 20 Km respectively.

For every Guard band (GB), all distances are varied accordingly until 20Km is reached which is the maximum DVB-T coverage radius. The process is continued by increasing GB until 8.5 MHz is reached.
Using the interference calculator developed and considering that the DVB-T receiver is located in the interfering cell (Figure.8), graphs are thus produced for:

1. DVB-T and ACI signal strength
2. Signal to ACI Ratio
3. Outage probabilities
4. DVB-T signal strength as it varies with pathloss.

Table.1 shows the typical parameters considered in producing the graphs. The interference calculator developed is very dynamic as it allows parameters to be varied depending on the objective(s) of the user.
These findings are essential as it gives an insight to finding a co-existence relationship between these radio communication systems.

Table.1 DVB-T and UMTS parameters considered for simulation (Hamacher, 2002)

Parameters	DVB-T	UMTS
Cell Radius	20Km	1Km
TX Mobile Station(MS) Power	Receive only mode	24dBm
TX Base Station (BS) Power	74Bm(20KW)	43dBm
Antenna height (BS)	100m-300m	30m-50m
Antenna height(MS)	1.5m	1.5m
Noise level	-98dBm	-100dBm
Antenna type	Omni	Omni/Sectorized
Orthogonality factor	Not applicable	0.3
Channel Spacing	8 MHz	5 MHz
Width of interference region	Not applicable	8 cm
Centre Frequency	2140 MHz- Separation frequency	2140 MHz
Interference angle	90 degrees	20 degrees
Service type	Broadcast	Unicast

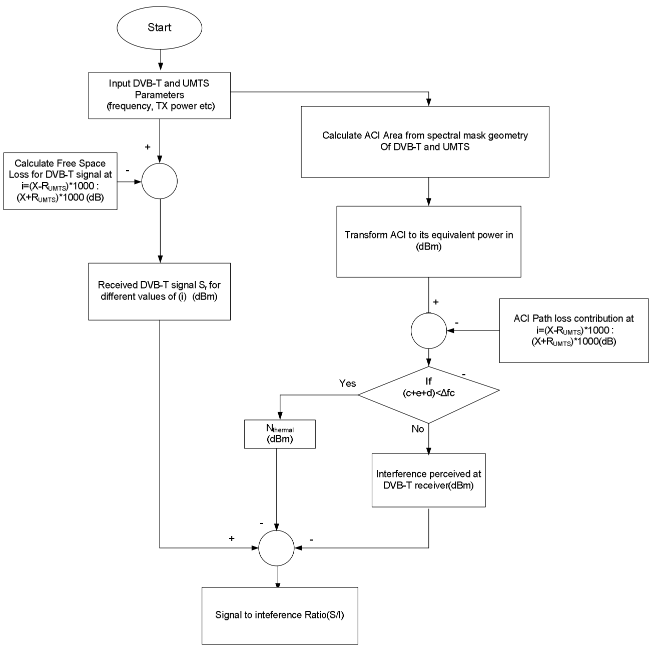
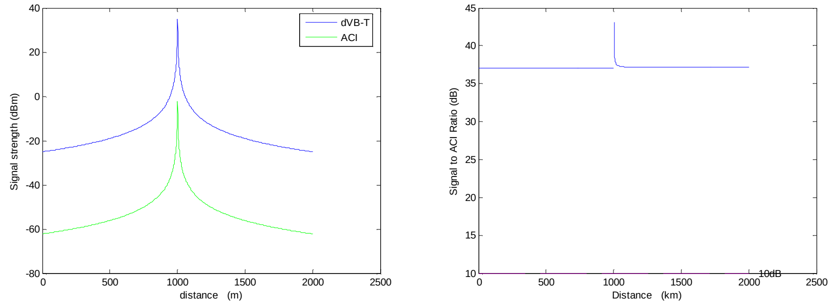


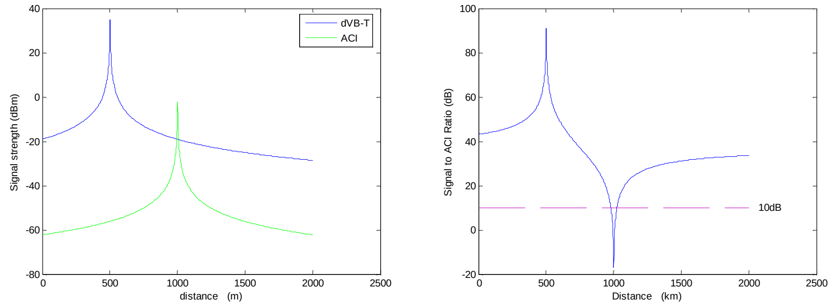
Chart 1: Flow chart of the interference calculator.

Simulation Results and Graphs

Graphs of DVB-T and ACI Signal Strength Against UMTS BS Coverage Distance at Varying Distances of X (Km) of DVB-T transmitter to UMTS BS(Down link) when Frequency of separation is 5 MHz on the Left Hand Side(LHS) and Its associated Signal to ACI Ratio under the same condition on the Right hand side(RHS)



X=0



X=0.5

Figure.9a: DVB-T and ACI Signal Strength against UMTS BS Coverage and Its associated Signal to ACI Ratio under the same condition (Δf_c= 5MHz)

It would be observed from the graphs that at X=0, which depicts the co-location scenario explained earlier, Figure.4, gives the best co-existence relationship since a DVB-T receiver does not experience any form of degradation at this condition. At X=0.5 Km , ACI is still greatly subdued with high quality reception due to short distance from the DVB-T Transmitter since the DVB-T TX power is much higher than its interfering power. Same explanation is only logical for X=1 Km.
Note: Acceptable minimum Carrier to Interference ratio for quality DVB-T reception is 10dB as depicted in the graph.

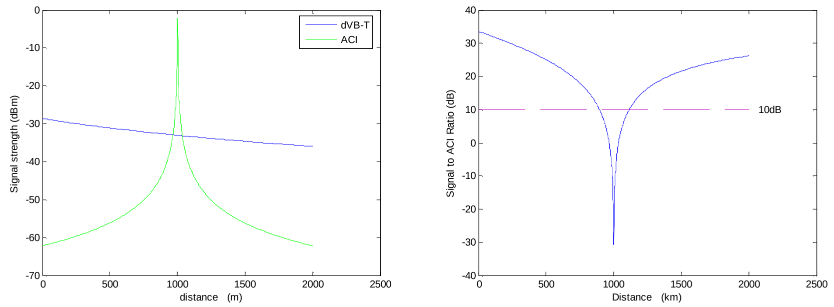
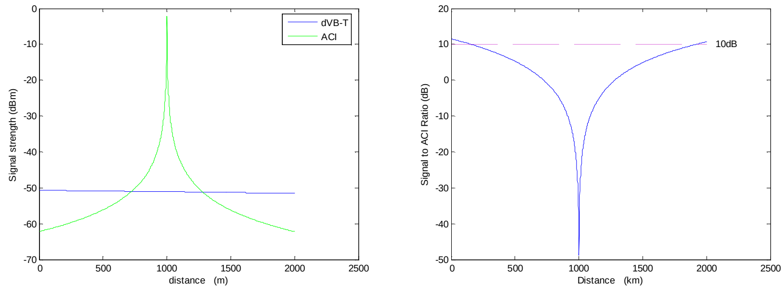


Figure.9b
X=2

An interesting scene unfolds here when the physical separation distance increases DVB-T Signal quality begins to deteriorate with increasing distance. This is logical since the DVB-T TX signal decreases with distance due to pathloss, while ACI is still strong in the interferer’s coverage where the interfered is located.

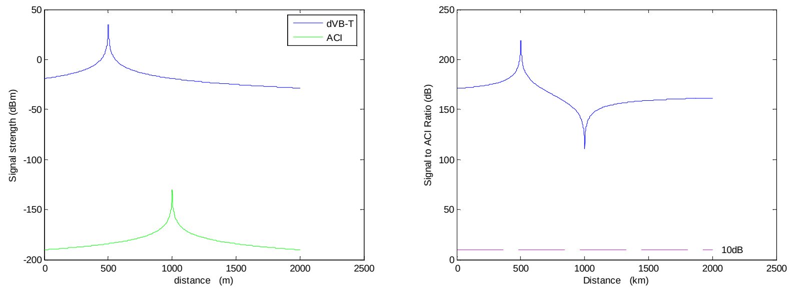


X= 20

Figure.9c

With high distance of separation, ACI becomes predominant and its effect far outways the DVB-T signal. A frequency separation of 5MHz is unrealistic and totally unacceptable.

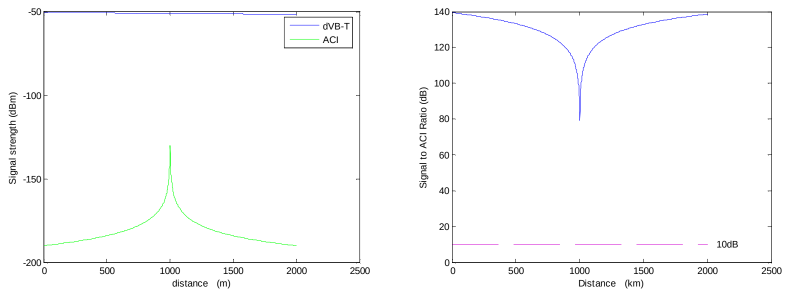
Graph of DVB-T and ACI Signal Strength Against UMTS BS Coverage Distance at Varying Distances of X (Km) of DVB-T transmitter to UMTS BS(Down link) when Frequency of separation is 15 MHz on the Left Hand Side and Its associated Signal to ACI Ratio under the same condition on the Right hand side



X= 0.5

Figure.10a: DVB-T and ACI Signal Strength against UMTS BS Coverage and Its associated Signal to ACI Ratio under the same condition (Δf_c= 15 MHz)

At 15MHz separation and above, there is no ACI. Adequate reception is achieved irrespective of separation distance.



X= 20

Figure.10b

This is an overall excellent condition but bandwidth is wasted, hence Δf_c= 5 and 6 MHz are seen as viable options to be explored for optimum co-existence relationship.

Table.1 shows the percentage outage probability defined as the probability that a DVB-T receiver would be in deep fades. This is a function of the Guard band and the physical separation distance between the participating Base Stations.

Threshold = 8.70%

Table.1: Showing Outage probabilities (OP) alongside corresponding distances and Guard Bands

GB / X(Km)	MHz 0 Δf_c=6.5	MHz 1 Δf_c=7.5	MHz 2 Δf_c= 8.5	MHz 3.5 Δf_c=10	MHz 5 Δf_c=11.5	MHz 6 Δf_c=12.5	MHz 8.5 Δf_c=15
0.00	0.00 %	0.00 %	0.00%	0.00%	0.00%	0.00%	0.00%
0.50	2.17%	1.09%	0.65%	0.22%	0.20%	0.02%	0.00%
1.00	3.26%	2.17%	1.74%	1.30%	1.30%	0.20%	0.00%
2.50	8.70%	7.61%	6.52%	5.43%	3.26%	2.17%	0.00%
5.00	17.39%	15.23%	14.13%	9.78%	6.50%	4.35%	0.00%
7.50	27.17%	23.91%	20.65%	15.22%	8.70%	6.52%	0.00%
10.00	36.96%	30.43%	27.17%	20.65%	14.1%	8.70%	0.00%
12.50	43.48%	39.13%	33.70%	26.09%	17.39%	10.87%	0.00%
15.00	54.35%	47.83%	39.13%	30.43%	19.57%	13.04%	0.00%
20.00	71.74%	63.04%	57.61%	40.23 %	28.26%	17.39%	0.00%

It should be noted that when (c+e+d)<Δf_c there would be no ACI but at other times ACI would occur. This situation is typical when GB=8.5 in Table.1, where there is no ACI.

A threshold is set for the OP to be 8.70%. this translate to an availability of 91.3%. This means that whenever a DVB-T receiver is under the coverage of an interfering UMTS BS, decodable signals are received in only 91.23% of the total area.

A guard Band of 5MHz would be conveniently chosen where the threshold is reached at a distance of 7.5km.

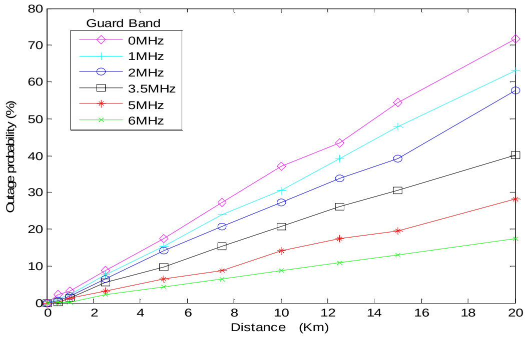


Figure.10: Outage probability against distance at various Guard bands

Figure.10 shows a pictorial representation of outages with distance at various Guard bands.
A guard band of 6MHz give approximately the smallest outages achieved for this simulation. It can be observed that at a distance of approximately 7.5Km, only GB of 5 and 6MHz gives best performance and outage probability less than 9%. At higher distances outage increases. DVB-T repeater stations might be considered in at higher distances which is a cost solution.

RESULTS AND DISCUSSION
It would be seen that the most appropriate carrier spacing needed would be when Δf_c=11.5 MHz (GB=5MHz). At X=7.5 Km and below, it still maintains a considerable measure of acceptable DVB-T signal and low outages. It can also be inferred from this study that the best way to reduce Adjacent Channel Interference is to co-locate the DVB-T and UMTS BS operating in adjacent bands typified when X=0 for all graphs otherwise at distance X apart, the Δf_c=11.5 MHz is preferred.

Graphs for Δf_c=12.5 MHz (GB= 6MHz) and Δf_c=15 MHz(GB=8.5MHz) was also produced along with their associated capacity, slight improvement was observed for the former and no ACI for the later since the it has been earlier intuited that when (d+c+e) is less than the carrier spacing (Δf_c) ACI cease to occur.

As distance X increases ACI becomes predominant when operating in adjacent bands due to pathloss. Since GB reduces the effect of ACI, it becomes imperative to find an optimum value at which these RANs can bearably co-exist with minimum outages, since spectrum is a limited resource. Hence looking for an optimum guard band becomes desirable to the operator and should not be at the expense of its customers bearing in mind they need the best quality of Service and(or) grade of service having access to the carrier as and when due with minimal interference and outages.

It can also be advised that under no circumstance should a DVB-T receiver be placed directly beneath its interferer as these would be totally blinded (i.e in deep fades) and there would be no reception. At distances away from the interferer where the required signal power drops severely an amplifier could be used at the DVB-T receiver to boost the weak signal strength.

Some manufacturers (Radio-Electronic, 2010) have designed and built very good filters that filter unwanted signals from the required signal. As receivers become more and more ideal, ACI and other forms of interference would become reduced.

RECOMMENDATIONS
DVB-T repeater station could be placed every 7.5Km radius. This reduces or eliminates outages in its coverage area (this has cost implications).

Decreasing the Interferer coverage area, which also increases capacity of UMTS users (also has cost implications because of increased Base stations, complexity of network, and frequent handovers).

Increase total available DVB-T transmitter power (has health and radiation implications)

Decrease total available UMTS base station power, this means increasing the terminal power. (has health implications, and interference caused by mobile may become significant).

Solution 1 is therefore ultimately recommended when spectrum becomes the biggest constraint.

CONCLUSION
Increase in guard band reduces or eliminates ACI when operating in adjacent bands, however considerable amount of spectrum would have been wasted, bearing in mind that 1MHz of spectrum could be licensed for several millions of Great Britain Pounds therefore an optimum guard band is sorted.

At a distance of about 7.5Km, GB of 5MHz is chosen, because it gives a bearable percentage outage probability and solutions are implemented as enumerated in the recommendations, outage would drop to its barest minimum because of a constructive superposition of DVB-T signals.

REFERENCES
Hamacher, Ch. (Germany, 2002a), "The concepts for management of DSA boarder Interference between DVB-T and UMTS". Chair of communications networks- Aachen University.

Hamacher , Ch. (Germany.2002b), "Required Guard bands for Co-operation of DVB-T and UMTS " ComNets-RWTH Aaechen

Leaves, P. Breveglieri, M. Grandblaise,D. Hamacher, C. (2004), "Spectrum Efficient Uni- and Multicast Services over Dynamic Multi-Radio Networks in Vehicular Environments", 16/02/2004) Authors: Paul Leaves (Editor), Participant(s): Fabien Migneret, UniS, TEI, CRM, RWTH, FT.

Owens, T. Zhang, C. Itagaki, T. (2006) "Radio spectrum, traffic engineering and resource management" http://bura.brunel.ac.uk/retrieve/7513/license.txt

EDU: 2010 www.ebu.ch/en/technical/.../trev_305-editorial.html

3gpp: 2010 http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_04/Docs/ pdfs/RP-99387.pdf

Radio- elect: http://www.radio-electronics.com/info/electronics-design/emc/rfi-filters-emc-filter-design.php

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